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BULLETIN

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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM OF THE

PRINCETON MEETING

AT

PRINCETON UNIVERSITY

PRINCETON, NEW JERSEY

JUNE 23 AND 24, 1939

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
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The American Physical Society

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JUNE 10, 1939 Vol. 14, No. 3

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PRINCETON MEETING, JUNE 23 AND 24, 1939

(Eastern Daylight Saving Time)

THE 229th regular meeting of the American Physical Society will be held in Princeton, New Jersey on Friday and Saturday, June 23 and 24, 1939 at Princeton University. All scientific sessions will be held in the Palmer Laboratory. The first session of the meeting will be at 9:30 o'clock, Friday morning, June 23, Daylight Saving Time.

Symposium. On Friday morning, June 23 at 9:30 o'clock in Room 301 of the Palmer Laboratory there will be a symposium of invited papers on nuclear fission. Dr. M. A. Tuve of the Carnegie Institution of Washington will speak on the "Discussion of Experimental Information Regarding Fission Processes" and Professor John A. Wheeler of Princeton University will speak on "The Mechanism of the Nuclear Fission."

Dinner. There will be an informal dinner in Proctor Hall at the Graduate College at 7:30 o'clock on Friday evening. Tickets at $1.25 each may be purchased at the registration desk in the Palmer Laboratory until 2 P.M. on Friday afternoon. It would be of greatest convenience if reservations for the dinner were made on the blank below so that the local committee can know as soon as possible how many to expect.

Registration. Registration ($1.00 per family) will open on the afternoon of Thursday, June 22 at 2:00 o'clock in the Palmer Laboratory.

Accommodations. Arrangements have been made for rooms as follows:

Princeton Graduate College: Only men can be accommodated here. Single occupancy, $2.00 per night; two in a room (two beds), $1.50 per night per person; breakfast, $0.50. Because of the limited number of rooms available it is requested that every guest who can do so should plan to room with a friend.

The Princeton Inn: Single room, $2.50 per night; two in a room, $2.00 per night; breakfast, $0.50. Only a small number of rooms will be available at the Inn.

The Nassau Tavern: $2.50 per night per person for both single and double rooms. Most of the rooms are double. Breakfasts from $0.40 up. The Tavern is the most centrally located of the three.

Since the total number of available rooms is not large it is suggested that you make your reservation by filling in and returning the coupon below *as soon as possible*. The local committee will endeavor to make arrangements in accord with the wishes expressed. Notification of reservations will be sent.

Entertainment. Tours of the University, to several private gardens and other points of interest, will be arranged. Facilities for golf, tennis and swimming will be available. The Department of Physics will give a garden party on Friday afternoon and a picnic on Saturday afternoon for members and guests.

Railroad Rates. Consult your local passenger agent for special rates which are available from many points to the New York World's Fair.

Summer Meeting at Stanford University. The summer meeting on the Pacific Coast will be held at Stanford University, California on Wednesday, Thursday and Friday, June 28, 29 and 30, 1939 as a joint meeting with the Astronomical Society of the Pacific.

JUN 12 1939

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936 the Society voted that:

No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

229. June 28–30, 1939. Stanford University, California.
230. December 1–2, 1939. Chicago, Illinois.
231. December, 1939. Pacific Coast. Time and place not yet decided.
232. December 28–30, 1939. Annual Meeting. Columbus, Ohio.
233. February 22–24, 1940. New York, N. Y.

W. L. Severinghaus, *Secretary*
Columbia University, New York, N. Y.

June 10, 1939.

CALENDAR

Eastern Daylight Saving Time

Thursday Afternoon, June 22

2:00 o'clock: Registration starts in Palmer Laboratory.

Friday Morning, June 23

9:30 o'clock: Palmer Laboratory: Room 301: Symposium on *Nuclear Fission:* Speakers—Dr. M. A. Tuve and Professor John A. Wheeler: See page 7.

10:45 o'clock: Fine Hall: Room 114: Meeting of the Council.

11:00 o'clock: Palmer Laboratory: Room 301: Papers No. 1–7. See pages 7–8.

11:00 o'clock: Palmer Laboratory: Room 303: Papers No. 8–13. See pages 8–10.

11:00 o'clock: Palmer Laboratory: Room 309: Papers No. 14–19. See pages 10–11.

Friday Afternoon, June 23

2:00 o'clock: Close of sale of tickets for dinner.

2:00 o'clock: Tours of campus starting every hour on the hour from Stanhope Hall. Informal sports.

5:30 o'clock: Garden party at the home of Mr. and Mrs. Henry DeWolf Smyth.

Friday Evening, June 23

7:30 o'clock: Proctor Hall at the Graduate College: Dinner.

Saturday Morning, June 24

9:30 o'clock: Palmer Laboratory: Room 301: Papers No. 20–31. See pages 11–14.

9:30 o'clock: Palmer Laboratory: Room 303: Papers No. 32–43. See pages 14–16.

9:30 o'clock: Palmer Laboratory: Room 309: Papers No. 44–54. See pages 16–19.

10:00 o'clock: Tours to Princeton gardens and other points of interest.

Saturday Afternoon, June 24

Picnic.

If you plan to attend the meeting please fill out and mail this advance registration card promptly. It will greatly facilitate the efforts of the local committee in making arrangements.

ADVANCE REGISTRATION CARD

American Physical Society

PRINCETON MEETING, JUNE 23 AND 24, 1939

Please return this card at once if you expect to attend the meeting.

Name. . . . . .
Last name First name Initials

I plan to go to Princeton by { Automobile ☐ / Train ☐ } arriving about { Thursday A.M. ☐ P.M. ☐ / Friday A.M. ☐ P.M. ☐ }

leaving about { Saturday A.M. ☐ P.M. ☐ / Sunday A.M. ☐ P.M. ☐ } . I am interested in { tennis ☐ / swimming ☐. / golf ☐ }

I should like accommodations as follows:

Single room { for man ☐ / for woman ☐ }

Room with another { with wife ☐ preferably at. . . . . / with. . . . . ☐ My second choice is. . . . . }

Please reserve. . . . . tickets for dinner on Friday at $1.25.

Please acknowledge the reservation by writing to me at . . . . . .

Return this card to Department Secretary, Palmer Laboratory, Princeton, N. J.

PROGRAM

FRIDAY MORNING AT 9:30 O'CLOCK

Palmer Laboratory, Room 301

SYMPOSIUM OF INVITED PAPERS

ON

NUCLEAR FISSION

1. **Discussion of Experimental Information Regarding Fission Processes.** M. A. TUVE, *Carnegie Institution of Washington.* (30 minutes.)
2. **The Mechanism of the Nuclear Fission.** JOHN A. WHEELER, *Princeton University.* (30 minutes.)

FRIDAY MORNING AT 11:00 O'CLOCK

Palmer Laboratory, Room 301

1. Transmutation of Boron by Deuterons. ERNEST POLLARD, W. L. DAVIDSON, JR. AND HOWARD SCHULTZ, *Yale University.*—The emission of charged particles by boron under bombardment by 3.5 Mev deuterons from a cyclotron has been studied. An absorption curve shows that the energy spectrum is complex, at least four groups being present. Of these, one is identified with the reaction

$$B^{10}+D^{2}\rightarrow Be^{8}+He^{4}$$

as studied by Cockcroft and Lewis. Two others are due to the reaction

$$B^{10}+D^{2}\rightarrow B^{11}+H^{1}$$

giving excited states of B^{11}. The fourth, a relatively intense group, has a range of 30 ± 3 cm and is possibly due to the reaction

$$B^{11}+D^{2}\rightarrow B^{*12}+H^{1}.$$

If this interpretation is correct, the value 12.0172 can be deduced for the mass of B^{*12}, which is in reasonable agreement with the value expected from the inspection upper limit of the β-ray spectrum.

2. Proton Induced Radioactivity in Fluorine and Sodium. E. C. CREUTZ, M. G. WHITE, L. A. DELSASSO, J. G. FOX, *Princeton University.*—Bombardment of fluorine and sodium with 5.3 Mv protons has yielded two new positron emitting isotopes which probably arise from the reactions $F^{19}(p,n)Ne^{19}$ and $Na^{23}(p,n)Mg^{23}$. Both these reactions are of theoretical interest because Ne^{19} and Mg^{23} have a proton excess of unity while F^{19} and Na^{23} have a neutron excess of unity. Wigner and others have pointed out that if one assumes *n-n*, *n-p*, *p-p* forces equal, then in the above nuclear types the difference in binding energy is due solely to the Coulomb repulsion of the protons. Taking the volume of the nucleus proportional to the number of particles one may calculate, from simple electrostatic considerations, the expected upper limit of the positron spectrum and hence the half-life and reaction threshold. On these grounds the threshold for the $F^{19}(p,n)Ne^{19}$ reaction should be about 4.2 Mv and the half-life approximately 40 sec. We bombarded several fluorine compounds and found a 20-sec. period with a reaction threshold of about 4.2 Mv. Similarly one expects the reaction $Na^{23}(p,n)$ to commence at about 5.0 Mv, the resulting Mg^{23} decaying with a half-life of 9 sec. Bombardment of Na metal in an atmosphere of hydrogen gave a 12.4 sec. positron emitter with a threshold somewhat above 5 Mv.

3. The Neutrons from the Disintegration of Fluorine by Deuterons. T. W. BONNER, *Cavendish Laboratory, Cambridge University.*—The neutrons from the disintegration of fluorine by deuterons have been investigated by the method of observing helium or hydrogen recoils in a high pressure cloud chamber. When targets containing fluorine were bombarded with 950 kv deuterons, several groups of neutrons were observed. The disintegration Q values computed from the energies of the neutron groups are 10.80, 9.33, 6.62, 5.39, 3.53, 1.84 and 0.74 Mev. The nuclear reaction appears to be (F^{19}, H^{2}; Ne^{20}, n'). The disintegration value $Q=10.80\pm0.20$ Mev corresponds to a transition to the ground state of Ne^{20} and the smaller Q values indicate excited states in Ne at 1.5, 4.2, 5.4, 7.3, 9.0 and 10.1 Mev. Only a small fraction of the neutrons belong to the group of maximum energy. The excited states in Ne^{20} at 5.4, 7.3, 9.0 and 10.1 Mev are unstable against alpha-particle emission and so may break up into O^{16} and an alpha-particle. The experimental width of the level in Ne^{20} at 10.1 Mev appears to be not greater than about 0.3 or 0.4 Mev.

4. Search for β and Delayed γ-Radiation from the *d-d* Reaction. M. H. KANNER AND W. T. HARRIS, *Princeton University.*—Recent results of Bonner[1] indicate the probable existence of an excited state of He^{3} 1.85

Mev above the ground state resulting from the reaction $d(d,n)He^3$. Bonner finds 10 percent of the reaction has $Q=1.48$ Mev compared with $Q=3.32$ Mev for the reaction leading to the ground state of He^3. A search has been made for the β-radiation which would result from either of the following processes:

$$He^{3*} \rightarrow He^3 + \gamma \quad \text{(Internally converted)},$$
$$He^{3*} \rightarrow H^3 + e^+ \quad \text{(Upper limit 0.8 Mev)}.$$

Observations made by means of a coincidence counter sensitive to β-rays of energy greater than 0.23 Mev during bombardment of D_2O by 135 kv deuterons gave less than one in 5×10^{-3} of the expected effect if either process were in equilibrium with the reaction. β- and γ-rays of long life were sought by letting the He^3 from the target enter a separate vacuum chamber through a foil of 1.2 mm stopping power. This chamber could be sealed off from or connected to the main vacuum system by a stopcock, and measurements were made after alternating bombardments with the stopcock open or closed. No measurable β- or γ-radiation was observed. From the intensities used we calculate that if He^{3*} emits e^+, the lifetime is greater than 10 days, and that if it is γ-active, the lifetime is longer than $\frac{1}{2}$ hr.

[1] Bonner, Nature **143**, 681 (1939); Phys. Rev. **52**, 685 (1937), **53**, 711 (1938).

5. Total Cross Sections of Carbon, Sodium, Magnesium and Aluminum for Fast Neutrons. MALCOLM MACPHAIL AND JOSEPH GIARRATANA, *Princeton University*.—The total cross sections of the above-named elements have been studied as a function of neutron energy for energies from 2.2 Mev to 2.78 Mev. While resonance is exhibited in the case of aluminum and magnesium, no such effect appears for carbon and sodium. The width of the resonance peak for aluminum is of the order of 300 kilovolts and extends from 2.45 Mev to 2.75 Mev. For magnesium the peak begins at about 2.50 Mev and continues beyond the maximum energy of neutrons used. As a source of neutrons we have used a heavy ice target bombarded by 100 kilovolt deuterons. The energy of the neutrons from this reaction is a function of the angle of emission relative to the incident deuteron beam, varying from 2.1 Mev to 2.78 Mev.

6. Scattering of Alpha-Particles by Nitrogen. GORDON BRUBAKER,* *Yale University*.—The anomalous scattering of alpha-particles from RaC′ by nitrogen nuclei into four different ranges of angles has been investigated. The mean angles of scattering were approximately 53°, 66°, 87° and 105°, the total angular spread being about 36° in each case. The occurrence of resonance effects in disintegration processes produced when nitrogen is bombarded by alpha-particles indicates that similar effects should be observed in the scattering of alpha-particles. The results show that the ratio of observed to classical scattering is not a smooth function of alpha-particle energy, the irregularities being attributable to resonance phenomena. The course of the scattering anomalies varies quite rapidly with angle.

* Sterling Fellow.

7. Beryllium Targets for Nuclear Research. MALCOLM C. HENDERSON, *Princeton University*.—Several methods of making satisfactory "thick" beryllium targets have appeared recently.[1, 2, 3] A simple method for making "thin" targets of beryllium seems to have been overlooked. It is possible to electrolyze Be directly from a mixture of fused fluorides at reasonable temperatures. The procedure is outlined in papers contained in "Beryllium, Its Production and Application" published by the *Zentrallstelle für Wissenschaftlich-Technische Forschungsarbeiten des Siemens-Konzerns*, translated by Rimbach and Michel and handled by the book department of the Chemical Catalogue Company, 419 Fifth Avenue, New York City. The electrolyte is a mixture of equal parts by weight of sodium fluoride and beryllium oxyfluoride. The latter salt is easily prepared by dissolving Be, BeO, $Be(OH)_2$, or $BeCO_3$ in HF and evaporating to dryness. The mixture melts below 500°C. The electrolysis can be carried out in a graphite crucible, which also acts as anode. The recommended temperatures vary with the cathode employed: for Al, below 600°; for Cu, 750°; and for iron and nickel, about 900°. The deposits are uniform and almost black, adhere strongly to the cathode if not too thick, and seem to be pure beryllium. Sample targets will be shown. It has proved to be difficult to get targets thicker than a few thousandths of an inch and still have much mechanical strength. The current densities employed are of the order of 0.1 amp./cm². At densities nearer 1.0 amp./cm² there is less diffusion of Be into the cathode material and for the thinnest layers such densities are better.

[1] H. R. Crane, Rev. Sci. Inst. **9**, 428 (1938).
[2] T. R. Folsom and G. Ferlazzo, A. A. A. S. meeting, Dec. 28, 1936.
[3] Van Atta, Clogston and Puls, Rev. Sci. Inst. **10**, 148 (1939).

FRIDAY MORNING AT 11:00 O'CLOCK

Palmer Laboratory, Room 303

8. Specific Heat and the Double Minima Problem of the NH_3 Molecule. R. F. HAUPT AND E. TELLER, *George Washington University*.—The specific heats of ammonia over the temperature range 0° to 150°C have been calculated. To determine the contribution of the vibrational degrees of freedom the known frequencies of the normal vibrations[1] were used in the Planck-Einstein formula. Comparison of observed values[2] with the calculated values indicated that the anharmonicities known to exist in the normal vibration of lowest frequency should be taken into

consideration. The anharmonic energy levels then substituted were those calculated by Manning[3] who made use of a double minima potential. This improved the agreement with experimental values considerably. Still better agreement was obtained by taking into account the effects of centrifugal force[4] and interaction of vibration and rotation. The latter causes a considerable change in the state where the molecule has just enough energy to pass from one minimum to the other. The agreement between the observed and final calculated values is within the experimental error of the observed specific heats.

[1] H. Sponer, *Molekülspektren* (Berlin, 1935).
[2] N. S. Osborne, H. F. Stimson, T. S. Sligh, Jr. and C. S. Cragoe, Nat. Bur. Stand. Sci. Pap. **20**, 65 (1925), No. 501.
[3] M. F. Manning, J. Chem. Phys. **3**, 136 (1935).
[4] E. B. Wilson, J. Chem. Phys. **4**, 526 (1936).

9. Dissociation of Hydrocarbons by Electron Impact. J. DELFOSSE AND WALKER BLEAKNEY, *Princeton University.*—The gases, propane, propylene and allene, have been examined with the mass spectrograph and the appearance potentials of the most important ions have been measured. Although little is known concerning the energies of the various free radicals formed, it is nevertheless possible to specify uniquely most of the reactions which lead to the observed ions. Upper limits may in turn be placed on the ionization potentials of the free radicals themselves. These limits fall in the range 9 to 12 volts. The ionization potentials of propane, propylene and allene were observed at 11.3, 10.0 and 9.9 volts, respectively. More than sixty ions were observed in the three compounds.

10. Dissociation of H_2O Vapor by Electron Impact. ANDREW HUSTRULID, MARVIN M. MANN AND JOHN T. TATE, *University of Minnesota.*—A mass spectroscopic study of the products of dissociation in water vapor has been made. The ions which have been observed, their relative abundances for an electron energy of 100 volts, and their appearance potentials, are listed in Table I.

TABLE I

ION	ABUNDANCE	APP. POTENTIAL (VOLTS)
H_2O^+	100.00	13.0±0.2
OH^+	23.2	18.7±0.2
O^+	1.7	26.3±0.5
H_3O^+	0.7	13.8±0.5
O^-	0.12	7.5±0.3
		23.7±0.5
		36 ±3.0

We have found no evidence for higher ionization potentials of water, in contrast with the results of Smyth and Mueller.[1] The relative abundance of H_3O^+ is a function of the pressure. (Resonance) peaks have been observed for H_1^-, having maxima at 7.2 and 9.1±0.3 volts, and for O^- at 8.8, 11.0 and 13.2±0.3 volts. The probable processes by which the various ions are formed will be discussed.

[1] Smyth and Mueller, Phys. Rev. **43**, 116 (1933).

11. A Multiple Nomogram for the Atomic Constants. RICHARD A. BETH, *Worcester Polytechnic Institute.*—It seems worth while to investigate the existing discrepancy among the precision measurements of quantities of the form $f=ke^{\alpha}m^{\beta}h^{\gamma}$ both analytically and graphically. The author has previously[1] emphasized the calculation of errors from the sum of the squares of the deviations of the least squares solution as a suggestive analytical approach. Graphic charts of the atomic constants have been of two kinds: (*a*) Charts in which the values of f are plotted along rectilinear axes at proper angles and in which a set of consistent values is denoted by a point.[2] (*b*) Nomograms or alignment charts in which the values of f are plotted along properly spaced parallel scales and in which a set of consistent values is denoted by a straight line crossing these scales. The Birge-Bond diagram is the classical example of this type. A continuous infinity of possible charts of both types exists. In all *two*-dimensional charts it is necessary to use an additional relation to reduce to *two* the *three* degrees of freedom in the f's; usually the measured value and Bohr formula for the Rydberg constant are so used, which puts this combination on a different footing from the other measured f's which appear on the diagram. The purpose of this paper is to illustrate how relations among the exponents of the form $a\alpha+b\beta+c\gamma=0$ may be used to make nomograms for those f's which satisfy the relation *without further assumptions.*[3] Furthermore, these groups may be combined on one diagram in such a way that the consistency among the groups may be tested by observing whether their consistency lines intersect on the proper scale. One of the infinitely many "multiple nomograms" of this type is obtained by arbitrarily assuming convenient reference values e_0, m_0, and h_0, which give f the value f_0, and laying off $z=(6000\log f/f_0-12\beta)/(3\alpha+6\beta+2\gamma)$ as a vertical scale for f at the abscissa $x=6(5\alpha+11\beta+5\gamma)/(3\alpha+6\beta+2\gamma)$. Consistency tests of values plotted on this diagram require only the use of a straight-edge and do not implicitly involve other measurements than those actually plotted on the diagram.

[1] R. A. Beth, Phys. Rev. **54**, 865 (1938).
[2] R. A. Beth, Phys. Rev. **53**, 681 (1938). J. W. M. DuMond has independently devised another diagram of this type.
[3] DuMond's chart of the (*a*) type implies the use of the relation $\alpha+\beta+\gamma=0$ in an analogous way.

12. Energies in the d^9p Configuration of the Nickel-Like and Palladium-Like Spectra. A. T. GOBLE, *Alfred University.*—The theory for internal coupling for two electron systems has been applied to the $3d^94p$ configurations of Ni I, Cu II, Zn III, Ga IV, and Ge V and the $4d^95p$ configurations of Pd I, Ag II, Cd III, In IV, and Sn V. The agreement between theory and experiment is excellent except for Ni I and Pd I where inter-configurational perturbations probably account for the discrepancies. Except for these two cases, no deviation of more than 3.5 percent of the triplet width due to the d^9 electrons occurs. Separate electrostatic parameters for each multiplet were used as in a previous calculation for the platinum-like spectra.[1] The expected relations between them hold fairly well, especially for the nickel-like spectra.

[1] A. T. Goble, Phys. Rev. **48**, 346 (1935).

13. Additions to the Arc Spectrum of Silver. A. G. SHENSTONE, *Princeton University.*—The silver arc spectrum is very inadequately analyzed. Observations in the Schumann region have revealed at least nine new combinations with the low ^2S state, but even with these it has not been possible as yet to discover the $d^9s^2\ ^2D$. This is probably due to the fact that ^2D overlaps the lowest ^2P state. One high level at -20161, probably $J=1\frac{1}{2}$, of $d^9ss\ ^4D$ has been found. The evidence of observations throughout the spectrum indicates that many lines have not been observed because of their extreme width. One of the ^2S combinations in the Schumann region is about 500 cm^{-1} wide. A line of such width in the visible would be quite undetectable with a large grating.

FRIDAY MORNING AT 11:00 O'CLOCK

Palmer Laboratory, Room 309

14. High Pressure Cloud Chamber. W. E. STEPHENS,* W. E. SHOUPP,* R. O. HAXBY* AND W. H. WELLS, *Westinghouse Research Laboratories.*—A high pressure cloud chamber 15 cm in diameter and designed to operate up to 30 atmospheres pressure has been constructed. The metal piston (velvet covered) is sealed with a rubber diaphragm and operated by the pressure in the backing chamber. This pressure is controlled by a relief valve with two springs. One of these springs is set for the expanded pressure; the other (in series) adds on to give the compressed pressure. This latter is controlled by a solenoid and its release causes the expansion. Pressure to operate the cloud chamber is obtained either from a small compressor or from tanks of compressed gas. A high pressure mercury arc lamp (Westinghouse 1000 watt H-6 water cooled mercury vapor lamp) is used for illumination, and provides ample cool light for photographing heavy particles. An all-electric timer (modified from Richardson's) has proven very convenient for use in conjunction with the chamber. Preliminary operation at four atmospheres of nitrogen (and ethyl alcohol) indicates that the cloud chamber is quite reliable.

* Westinghouse Research Fellow.

15. Specific Ionization Measurements and Sign Preference for Condensation in a Wilson Cloud Chamber. ROBERT B. BRODE AND G. DALE BAGLEY, *University of California.*—Previous measurements[1] of the specific ionization for high speed electrons, by counting the number of drops per cm along the tracks in a Wilson cloud chamber, have confirmed the predicted minimum ionization for electrons of $5\times10^3\ H\rho$ (2 Mev). These measurements indicated a mean specific ionization for electrons between one and 100 Mev, about one-half of the values obtained from ionization chamber measurements (i.e. 60 to 70). By changing the direction of the clearing field the tracks of the positive and negative ions were separated in the plane of focus of the camera. At ratios of expansion where considerable background was present there were on the average about 50 to 60 drops per cm in each track. As the expansion ratio was lowered, with water vapor in the chamber the positive ion track gradually disappeared leaving the density of drops in the negative track practically unchanged. By using a mixture of two parts ethyl alcohol and one part water as the source of vapor, the negative ion tracks were the first to disappear. The separation of the tracks and their diffusion give a measure of the mobility of the ions. Under the conditions of the experiments for measurement of specific ionization of high speed particles only the drops condensed on positive ions were counted so that the number of ion pairs per cm is to be taken as equal to the number of drops per cm. The minimum probable ionization is therefore about 50 ion pairs per cm of path in air at one atmosphere pressure and 0°C.

[1] Corson and Brode, Phys. Rev. **53**, 773 (1938).

16. The Nature of Cosmic-Ray Phenomena at High Altitudes. W. F. G. SWANN, *Bartol Research Foundation of the Franklin Institute.*—Bartol Foundation observations made in the stratosphere show a variation of cosmic-ray intensity with zenith angle θ which, at the highest altitude, is much less than would be expected if the intensity depended only upon $h \sec\theta$, where h is the distance from the top of the water equivalent atmosphere. While the magnetic deviation of the secondaries produced by pair production can be such as seriously to affect directional measurements in the stratosphere, it cannot be invoked as a complete explanation of the small zenith angle variation. It is suggested that certain of the primary rays give rise in the stratosphere to a situation in which secondaries are shot out more or less uniformly in all directions. Conservation of energy and momentum prohibit the realization of such a phenomenon in a single act, but it can take place through the intervention of an intermediary stage. As one of several possibilities, one can visualize a mesotron formation with subsequent disintegration of the mesotron. Those mesotrons which are formed at rest will have a mean life comparable with only 10^{-6} of a second and will disintegrate before they have left the stratosphere. Moreover, being sensibly at rest, their disintegration particles will, on the average, travel out equally in all directions.

17. The Angular Dispersion of the Cosmic Radiation in the Upper Atmosphere Resulting from the Deflection of Low Energy Particles in the Earth's Magnetic Field. THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute.*—In the interpretation of directional effects at sea level one may assume with close approxima-

tion that the rays which enter the instrument have the same direction as the primaries which produced them. At higher elevations this condition no longer holds and in order to estimate the diffuseness of the soft component for the interpretation of east-west asymmetry measurements a calculation has been made of the angular spread of secondary rays produced by deflections in the earth's field in the idealized case where the primary rays are incident unidirectionally from the vertical. Both radiation and ionization losses of energy have been taken into consideration and it is found that at a depth of 1 meter of water rays whose energies exceed 15 Mev lie within thirty degrees of the original direction and half of the intensity lies within five degrees. The beam broadens at higher elevations or when lower energies are included. The corrections to the recent east-west asymmetry measurements[1] because of this effect are wholly negligible.

[1] Phys. Rev. **55**, 503 (1939).

18. Evidence for Neutrons in the Cosmic Radiation. S. A. KORFF, *Bartol Research Foundation of the Franklin Institute.*—The intensity of neutrons in the cosmic radiation has been investigated. A series of free balloon flights has been carried out, employing neutron counters, and automatically transmitting the data to the ground station by short wave radio. The neutron counters were filled with boron-trifluoride gas.[1] The amplifying circuit was so adjusted that only pulses due to alpha-particles were detected. Such alpha-particles are produced by disintegration of the boron nucleus by slow neutrons. The arrangement is not sensitive to beta- or gamma-rays. Observations have been made up to 70,000 feet, or about half a meter of water equivalent below the top of the atmosphere. The evidence indicates a rapid rise of neutron intensity with elevation. The rate of increase is greater than that of the total intensity of cosmic radiation, and roughly equal to that of the large bursts observed by Montgomery.[2] At just less than one meter of water equivalent below the top of the atmosphere, or at about the peak of the cosmic ray intensity-*vs.*-altitude curve, the number of neutrons recorded is of the same order of magnitude as the number of electrons.

[1] S. A. Korff and W. E. Danforth, Phys. Rev. **55**, 980 (1939).
[2] C. G. and D. D. Montgomery, Phys. Rev. **47**, 429 (1935).

19. The Energy Production in the Sun. R. E. MARSHAK AND H. A. BETHE, *Cornell University.*—We have calculated the average energy production in the sun assuming that it is due to the capture of protons by protons and the carbon cycle.[1] The proton-proton reaction now gives about the same contribution to the energy as does the carbon cycle; this results from the use of a larger value of the Fermi β-decay constant than previously[2] and from the correct evaluation of the matrix element. The energy evolution turns out to be 5.0 ergs per gram-second on the "standard" model and 4.0 on the point-source (with convective core) model; this is to be compared with an observed value of 2 ergs per gram-second. In view of the accuracy of the calculations and the good agreement between the two models both as to the central temperatures and densities and the run of the temperature-density distribution, this large discrepancy cannot be overlooked. It is suggested that this disagreement is not serious but can be removed by assuming the presence of an appreciable amount of helium in the sun in addition to hydrogen and "Russell mixture." A helium content of about 15 percent, by reducing the opacity and therefore the temperature, brings the theoretical energy production down to the observed. Such a value is consistent with observations on the sun's atmosphere and does not affect the statistical arguments about the carbon cycle as the primary source of energy for the main sequence stars.

[1] H. A. Bethe, Phys. Rev. **55**, 434 (1939).
[2] B. O. Grönblom, Abstract at April meeting, 1939.
[3] G. Gamow, Astrophys. J. **89**, 130 (1939).

SATURDAY MORNING AT 9:30 O'CLOCK

Palmer Laboratory, Room 301

20. Magnetic Field Effect upon the Photoelectric Properties of Iron. N. KERMIT OLSON, *University of Washington. (Introduced by Donald H. Loughridge.)*—In a continuation of earlier work[1] photoelectric currents from electrolytic iron were studied as a function of magnetic field strength. The photoelectric cell was so arranged that a field up to 5000 gauss could be directed across a cylindrically shaped piece of iron whose surface had been electroplated with a thin layer of pure iron. The incident light beam, from a quartz monochromator, was perpendicular to the iron surface and also to the magnetic field. Photoelectric currents were measured by an FP-54 tube and light intensities by a Cartwright thermocouple. In all cases saturation currents were ensured by sufficiently high accelerating potentials. The usual Fowler curves were plotted for the analysis of the data. Within 100A from the long wave-length limit at 2615A an effect, in a direction such as to increase the work function of the metal, was found. This apparent shift in the long wave-length limit amounted to only a few Angstroms at 5000 gauss but was readily reproducible and increased nearly linearly with field strength. Unavoidable sources of error such as fluctuations of arc intensity, electrometer tube adjustments, and temperature changes, were minimized by taking alternate readings of the photoelectric current with the magnetic field on and off.

[1] Loughridge and Olson, Phys. Rev. **50**, 389 (1936); **54**, 239 (1938).

21. The Magnetic Structure of Electrolytically Polished Silicon-Iron Crystals. W. C. ELLMORE, *Swarthmore College.*—The magnetic structure of unstrained crystals of silicon-iron (ca. 3.5 percent Si) has been investigated by depositing colloidal magnetite upon electrolytically polished specimens. Each specimen, cut from annealed strip stock, contained several large crystals extending through the strip. The orientation of individual crystals was determined to $\pm 1°$ by etch reflections. In forming patterns, the polished specimens were placed on the large pole piece of an electromagnet mounted (with axis vertical) on a microscope stage of novel design. Typical colloid patterns characteristic of the demagnetized state will be illustrated. They differ from previously reported "maze" patterns found on mechanically polished specimens. By comparing the patterns on many crystals with the known crystal orientations it is possible to propose a layer-like magnetic structure which will account for many features of the patterns. In general the patterns are much more complex when there is no direction of easy magnetization parallel or nearly parallel to the exposed surface. This complexity can be attributed to a fine-scaled magnetic structure which is superposed on the layer structure and which appears to be localized near the surface. A similar situation occurs with cobalt crystals for cuts sufficiently inclined to the hexagonal axis.

22. The Variation of the Adiabatic Elastic Moduli of Ammonium Chloride with Temperature between 200°K and 273°K. A. W. LAWSON AND R. SCHEIB, *Columbia University.*—Dynamic measurements of the adiabatic Young's modulus and the adiabatic rigidity modulus of pressed ammonium chloride as a function of temperature in the region of its low temperature transition reveal no discontinuities in the elastic moduli. With rising temperature, a minimum in Young's modulus and a sharp decrease in the rigidity modulus occur at 242.8°K. The internal friction rises to a sharp maximum at the same temperature. Hysteresis occurs in all measurements over a range of 10°K about the transition temperature. These data, together with the observed temperature dependence of the coefficient of thermal expansion and specific heat at constant pressure, indicate that the maximum value of the latter quantity at the transition temperature is considerably larger than any previously reported. Furthermore, the difference between c_p and c_v is probably greater than hitherto suspected. These conclusions are confirmed by a preliminary measurement of the variation of the isothermal Young's modulus with temperature. The similarity in the behavior of ammonium chloride, quartz and β-brass suggests that this abnormal difference in specific heats is typical of order-disorder transitions. Better agreement is then to be expected between the empirical data and the formulae of existing statistical theories.

23. Elastic Constants of Single Crystals of the Alloy Cu_3Au. SIDNEY SIEGEL,* *Westinghouse Research Laboratories.*—Single crystal rods several inches long, $\frac{3}{16}$-inch diameter were grown from the melt in a vacuum furnace. The use of a high speed oil diffusion pump made it possible to maintain a residual gas pressure of 10^{-5} mm when the molten alloy was at 1000°C. The crystals were prepared from copper and gold which were both 99.99 percent pure, the composition of the alloy being 24.9 atomic percent Au, 75.1 percent Cu, as determined by chemical analysis. The crystals were maintained at 850°C for about 4 hours and then cooled to room temperature during the next 24 hours. The orientation of the cylinder axis of a single crystal rod was determined with x-rays, by using the back-reflection of the Laue method described by Greninger. The elastic constants were measured by means of the composite piezoelectric oscillator method. Values of Young's and the rigidity modulus were determined for 11 crystals of different orientations. The lattice of Cu_3Au is cubic, with three principal elastic constants; the room temperature values of these are:

$$S_{11} = 1.490 \times 10^{-12} \text{ cm}^2/\text{dyne},$$
$$S_{12} = -0.601 \times 10^{-12} \text{ cm}^2/\text{dyne},$$
$$S_{44} = 1.610 \times 10^{-12} \text{ cm}^2/\text{dyne}.$$

Measurements of these quantities as a function of temperature, and hence as a function of degree of order, are now being made over the temperature interval 20°C to 450°C.

* Westinghouse Research Fellow.

24. The Internal Friction of Zinc Crystals. T. A. READ, *Columbia University.*—The internal friction of zinc crystals has been measured as a function of the crystal orientation and the amplitude of oscillation, at frequencies of 39 and 78 kilocycles, for longitudinal oscillations. The method of measurement is a refinement of that of Cooke and Brown,[1] employing a composite piezoelectric oscillator and an alternating current bridge. The crystals are grown by a modification of the Bridgman method from zinc of high purity (99.999 percent) obtained through the generosity of the New Jersey Zinc Company. The experimental results show that the internal friction of a strain-free crystal is very low (logarithmic decrement less than 1.5×10^{-5}) for some sufficiently small amplitude of oscillation which depends on the orientation of the crystal. As the amplitude of oscillation is increased, the internal friction rises. Strained crystals have a higher internal friction than strain-free crystals.

[1] Cooke and Brown, Phys. Rev. **50**, 1158 (1936).

25. Low Temperature Transition Phenomena in Some Paramagnetic Salts. C. F. SQUIRE, *University of Pennsylvania.*—The temperature dependence (300°K to 40°K) of the magnetic susceptibility of the following Mn^{++} salts has been measured: MnO, MnS, MnSe, and MnTe. A "λ" point transition at low temperatures makes the susceptibility break away from a "spin only" law and decrease with lowering temperature. Each salt has its characteristic transition temperature, increasing with increasing molecular weight. Two separate methods were used to measure the susceptibility; an analytical balance for the force on the sample due to an inhomogeneous field, and an induction coil with a ballistic galvanometer. The lowest temperatures were obtained by the adiabatic desorption of hydrogen from charcoal. Evidence for the dependence of the susceptibility on the measuring field and for an hysteresis has been found on the low temperature side of the transition.

26. X-Ray Measurements of Compressibility. ROBERT BYRON JACOBS,* *Harvard University.*—The compressibilities of *copper* and *aluminum* have been measured with x-rays by using the Debye-Scherrer method. The x-ray camera operates with the sample under hydrostatic pressures as high as 5000 kg/cm² which has been described elsewhere.[1] For copper, the value obtained for the average compressibility $(\Delta V/V)\times(1/P)$ between 1 and 4500 kg/cm² is 6.87×10^{-7}. This compares with Bridgman's value[2] of 7.13×10^{-7}. Since the probable error in the former is almost 4 percent, the difference may not be altogether significant. However, for aluminum an x-ray value of 12.92×10^{-7} is obtained with a probable error of 0.5 as compared with Bridgman's value of 13.38×10^{-7}. It is possible that a real significance is attached to the lower compressibilities found by the x-ray method, since x-rays measure *lattice* compressions, rather than *over-all* compressions. The two are not necessarily the same in the mosaic theory of the solid state. The solid as a whole could possibly strain at a slightly different rate from the mosaic blocks themselves, due to the existence of "slack" during the initial stages of compression. This would, of course, result in an abnormally high initial macroscopic compressibility, and a very high pressure coefficient of compressibility. The first prediction seems to be borne out by the present results if the deviations are actually significant. Additional weight is given to the argument by the now well-known[3] fact that for a number of "hard" metals, the following theoretical equation $\gamma=B/A^2-1/6$ is not satisfied. For each of these metals, abnormally high measured value of the pressure coefficient of compressibility is indicated. It is possible, again, that these experimental values hold only for the macroscopic solid, and are another manifestation of "slack" in the solid state.

* Now Lalor Fellow in Physical Chemistry at Massachusetts Institute of Technology.
[1] R. B. Jacobs, Phys. Rev. **54**, 325 (1938).
[2] P. W. Bridgman, *The Physics of High Pressure*, p. 160.
[3] Mott and Jones (Oxford Press 1936), p. 22.

27. Order in the Copper-Gold Alloy System. L. H. GERMER AND F. E. HAWORTH, *Bell Telephone Laboratories.*—Films of copper-gold alloy, containing 75 atomic percent copper, have been examined by electron diffraction by the transmission method. These alloy films are prepared by vaporizing the alloy in vacuum upon a layer of Lucite on a microscope slide. This plastic is then stripped from the slide and dissolved in ethylene dichloride. The floating alloy film is caught from the liquid across a narrow slit. Electrons passed through the film give a diffraction pattern characteristic of randomly oriented crystals having a continuous range of compositions from gold to copper. When a film is heated in vacuum to 450°C and quenched, and then heated for a few hours at 196°C, the pattern from it exhibits the rings of the homogenized alloy, including rings corresponding to planes having mixed indices proving that the alloy is ordered. The intensities of these indicate that the ordering is complete. It is clear that long range order is produced at 196°C, although Sykes and Jones[1] have found that order detectable by x-rays is not produced by heating at 320°C. When a film in the original unmixed condition is heated, mixing begins at about 140°C, and ordering of an anomalous character occurs at 200°C.

[1] Sykes and Jones, Proc. Roy. Soc. **157**, 213 (1936).

28. Photoconductivity of Crystalline Willemite at Low Temperatures. R. HOFSTADTER AND R. C. HERMAN, *Princeton University.*—The photoconductivity of a natural single crystal of willemite has been studied for some of the mercury lines between 2300 and 4100A in vacuum at about −150°C. The color of this crystal suggests that a small manganese impurity is present. Electrical contact was made by pressing gold electrodes against two parallel polished faces of the crystal which had been sputtered with gold. Monochromatic light from a grating entered the crystal making an angle of about 40° with the normal. Incident energies were measured simultaneously with the photoconductivity by means of a calibrated sodium photoelectric cell kindly lent to us by the General Electric Company. At −150°C there is a peak of photoconductivity near 2965A. There is also some evidence of other structure. The same shape of curve was obtained whether the crystal was polarized or unpolarized. We observed qualitative agreement with these results when Aquadag electrodes were employed. The above information was obtained with an applied field of approximately 900 volts/cm. A voltage-current characteristic for the crystal in the unpolarized condition proved to be strictly linear up to the above field. We are grateful to the Department of Geology, Princeton University, for allowing us to use this willemite crystal and for their kind cooperation.

29. The Relationship Between Surface States and Energy Bands in Crystals. WILLIAM SHOCKLEY, *Bell Telephone Laboratories.*—In the paper of Tamm[1] in which the existence of surface wave functions at the boundary of a crystal is demonstrated and in Fowler's[2] later discussion, there is no analysis of the development of the surface states from the atomic states during the conventional conceptual process of forming the crystal by varying the lattice constant from infinity to a finite value. This problem is investigated for the case of a finite linear lattice of potential wells which are symmetrical about their centers but are otherwise arbitrary in shape. At large lattice constants the atomic energy levels split into bands of allowed levels none of which are surface levels. The surface levels occur only after the bands have crossed and are represented by the two isolated levels lying in the gaps. The new results from this investigation are first that crossing of the bands is essential for levels of the Tamm type and second that after the crossover the bands on either side of the energy gap have each lost one level so that the number of levels in each is less than the number of atoms.

[1] Ig. Tamm, Physik. Zeits. der Sowjetunion **1**, 733 (1932).
[2] R. H. Fowler, Proc. Roy. Soc. **141**, 56 (1933).

30. The Specific Heat of Nickel-Chromium Alloys. HORACE GROVER AND JOHN HUTZENLAUB, *Rensselaer Polytechnic Institute.*—As part of a program on the physical properties of metals and alloys, an apparatus of the type described by Sykes[1] has been constructed. Measurements

of the specific heat of electrolytic copper from 50°C to 600°C indicate a precision of about 2 percent. Some experimental difficulties encountered and some of the limitations of the present set-up will be discussed. The specific heat of an alloy of about 20 percent Co and 80 percent Ni has been measured over the available temperature range. A marked increase in the specific heat occurs at about 500°C. This may be correlated with the well-known anomaly in the electrical resistance. A more complete investigation of this anomaly is being undertaken.

[1] Sykes, Proc. Roy. Soc. **A143**, 422 (1935).

31. Zone Theory and the Properties of Sulfide Phosphors. R. P. JOHNSON, *General Electric Company.*—It can be shown by qualitative experiments that the instantaneous rate of decay of brightness of a sulfide phosphor after excitation is not a function solely of the quantity of residual light in the sample, and hence that neither a monomolecular nor a bimolecular mechanism will satisfactorily describe the decay. A plausible arrangement of concepts afforded by the simple zone theory of the solid insulator yields a model which accounts qualitatively for (1) decay characteristics at room temperature, (2) high efficiency of excitation, (3) effects of temperature on decay rates and efficiency, (4) photoconductivity, and (5) accelerated decay in the presence of infra-red radiation. It is imagined that after excitation, which is essentially an ionization of the activator atom, the dissociated electron is highly likely to be trapped and held localized in a discrete energy level in the forbidden region, recombining with an ion and emitting the characteristic luminescence only after it has been freed from this trapped state by thermal excitation or other means. This same picture, with suitable modifications, also accounts qualitatively for the luminescent behavior of silicate phosphors, which decay at first exponentially with a temperature-invariant rate.

SATURDAY MORNING AT 9:30 O'CLOCK

Palmer Laboratory, Room 303

32. Performance of a System of Modified Hertz Pumps. K. T. BAINBRIDGE AND H. G. VOGT, *Harvard University.*—The pumps differ from the original Hertz design as follows: (1) A sharp edged cylinder is used to core out the mercury vapor jet; (2) the pump volume has been reduced to improve the yield to the end volumes; (3) the axis of the mercury jet makes an angle of 8 degrees with the horizontal to prevent interruption of the jet action by condensed mercury drops; (4) a circulation pump has been added to the heavy end. The assembly of the pumps is compact and the simple means of support has permitted remarkable freedom from leaks and breakage for four years. As a result of these modifications, the speed of separation has been increased. The enrichment of the carbon isotopes is increased and that of neon is decreased slightly compared to that of standard Hertz pumps. By means of a magnetic spectrometer, analyses were made of the separation of the neon isotopes as a function of time for a considerable range of neon pressures and jet velocities. With twelve pumps, a single exponential function accurately describes the time dependence of the separation, the periods required to attain one-half the equilibrium separation varying from 19 to 60 minutes. The rapidity of the separation increases the value of the pumps for certain physical experiments.

33. The Design and Operation of a High Voltage Unit for Nuclear Investigations. I. A. GETTING,* H. G. VOGT, AND J. B. FISK,† *Harvard University.*—The Van de Graaff generator described[1] previously has been utilized with a high voltage tube similar to that used by Hill *et al.*[2] for producing ion beams of large intensity. The tube itself is hung vertically from the ceiling and the beam accelerated upward. As there is no physical contact between the tube and the high voltage body, other than a few light wires, no mechanical vibration is transmitted to the tube. The source of ions is a low voltage capillary arc of a new design. The capillary itself is made of Kovar lined with glass only a few thousandths of an inch thick. A source of this type has delivered a total positive ion current of 250 μa of which about 60 percent were protons. With another such source, a beam of 130 μa of unresolved heavy hydrogen ions has been used to bombard lithium at 500 kv. The production of neutrons was equivalent to at least 20 grams of radium-beryllium as measured by the activity induced in rhodium.

* Society of Fellows.
† At present at the University of North Carolina.
[1] J. B. Fisk and I. A. Getting, Phys. Rev. **53**, 916A (1938).
[2] A. G. Hill, W. W. Buechner, J. S. Clark, and J. B. Fisk, Phys. Rev. **55**, 463 (1939).

34. The Radiofrequency Spectrum of the HD Molecule in Magnetic Fields. J. M. B. KELLOGG, I. I. RABI, N. F. RAMSEY, JR. AND J. R. ZACHARIAS, *Columbia University and Hunter College.*—The HD molecule in the first rotational state has been investigated by the molecular beam magnetic resonance method. Nine lines arising from reorientations of the proton spin, twelve from reorientations of the deuteron spin, and another twelve from reorientations of the rotational angular momentum have been observed and identified. From these data one obtains the product of the magnetic moments of the proton and the deuteron, the electrical quadrupole interaction of the deuteron with the molecule, the rotational magnetic moment of the molecule, and the rotational magnetic fields at the positions of the nuclei. The results are in excellent agreement with the values of the various moments which were obtained from H_2 and D_2 molecules and are, there-

fore, an important confirmation of the existence of the deuteron quadrupole moment. The rotational fields at the proton and deuteron in HD are very nearly equal and are approximately 20.5 gauss, which is about $\frac{3}{4}$ of the rotational magnetic field in H_2. The value of the rotational magnetic moment of the molecule is found to be 0.661 ± 0.005 nuclear magneton. This is very nearly $\frac{3}{4}$ of 0.880, the value for H_2, so these moments are inversely proportional to the reduced masses.

35. Nuclear Magnetic Moments of $_5B^{10}$ and $_5B^{11}$. P. KUSCH AND S. MILLMAN, *Columbia University.*—The nuclear gyromagnetic ratios of the boron isotopes have been measured by the molecular beam magnetic resonance method, by using the molecules $Li_2B_4O_7$, $Na_2B_4O_7$, $K_2B_4O_7$, $NaBO_2$ and KBO_2. Two resonance minima were observed common to all of these compounds and must be attributed to the B^{10} and B^{11} nuclei. The g values deduced from these minima are 0.597 ± 0.003 and 1.788 ± 0.005, when referred to the g of Li^7 (2.167 in units of $e/2Mc$) as standard. A comparison of the observed depths of the resonance minima with the relative abundance of the two isotopes shows that the smaller g is to be assigned to B^{10}. Assuming plausible values for the nuclear spins, 1 for B^{10} and 3/2 for B^{11}, our results yield the magnetic moments of 0.597 and 2.694 nuclear magnetons for B^{10} and B^{11}, respectively. The signs of the nuclear moments are found to be positive.

36. Nuclear Magnetic Moment of $_{13}Al^{27}$. S. MILLMAN AND P. KUSCH, *Columbia University.*—The molecular beam magnetic resonance method has been applied to the study of the gyromagnetic properties of the A^{27} nucleus. The molecules $NaCl \cdot AlCl_3$ and $KCl \cdot AlCl_3$ yield, in addition to the known chlorine resonance curves, a common resonance minimum which we attribute to the Al^{27} nucleus. The nuclear g deduced from this minimum is 1.451 ± 0.004, when referred to the g of Li^7 as standard. From intensity measurements of hyperfine components of Al I lines Jackson and Kuhn[1] deduce a spin of 9/2 for the Al^{27} nucleus. Heyden and Ritschl[2] obtain a spin of 5/2 by applying the interval rule to the h.f.s. of Al II lines. It will be shown that a comparison of our g value with that calculated by means of the Goudsmit, Fermi-Segre formula from the observed splitting of the atomic energy levels fixes the nuclear spin of Al^{27} as 5/2. The magnetic moment is positive and has a value of 3.628 ± 0.010 nuclear magnetons.

[1] D. A. Jackson and H. Kuhn, Proc. Roy. Soc. **A164**, 48 (1938).
[2] M. Heyden and R. Ritschl, Zeits. f. Physik **108**, 739 (1938).

37. On the Saturation of Forces Derived from the Meson Theory. E. WIGNER AND L. EISENBUD, *Princeton University.*—On the basis of the meson theory nuclear interactions of the form

$$J_1(r)\{3(\mathbf{r}\cdot\mathbf{s}_1)(\mathbf{r}\cdot\mathbf{s}_2)/r^2-(\mathbf{s}_1\cdot\mathbf{s}_2)\}+J_2(r)(\mathbf{s}_1\cdot\mathbf{s}_2)+J_3(r) \quad (1)$$

with and without an additional charge exchange operator have been proposed. Forces of the general character of (1) are necessary for an understanding of the magnitude of the observed nuclear quadrupole moments. It can be shown that (1) does not have the property of saturation if, for two particles with spins parallel to a given direction, the potential (1) is negative for all r within a finite cone. One can prove this by considering a nucleus containing particles with spins parallel to the direction specified above and of the shape of an ellipsoid, the major axis of which is the altitude of the cone. By a proper choice of the minor axis of the ellipsoid the combined effect of the kinetic energy and the positive part of the potential energy can be made to be proportional to $n^{13/7}$, where n is the number of particles, while the negative part of the potential energy is still proportional to n^2. If the saturation requirement is to be maintained a potential of the type (1) satisfying the conditions required above cannot completely describe the interaction between nuclear particles. It is conceivable, however, that the interaction under the extreme conditions of our ellipsoidal model is strongly different from (1) but is sufficiently well approximated by (1) under conditions prevailing in real nuclei.

38. The Masses and Magnetic Moments of the Proton, Neutron and Deuteron. ENOS E. WITMER, *University of Pennsylvania.*—Within experimental error the magnetic moments of the proton, neutron, and deuteron are given by the formula $[(i^2+j^2)/(1^2+2^2+3^2)]3$ nuclear magnetons, where $i=2$, $j=3$ for the proton, $i=0$, $j=3$ for the neutron, and $i=0$, $j=2$ for the deuteron. A generalization of this applies to at least some other nuclei. This seems especially interesting in connection with the following regularity in the masses of these particles and the electron. The writer[1] pointed out that if M is the proton mass and m the electron mass, then $M/m=(7/2)^6=1838.266$. This may now be interpreted as $M=[(1^2+2^2+3^2)/2^2]^6 m$. Then the masses of the neutron and deuteron are well represented by

$$M_n=[(7/2)^6+7/2-1]m,$$
$$M_D=[2(7/2)^6-\tfrac{1}{2}\cdot 7/2]m.$$

It seems possible from the data that an extension of this scheme may give a good representation of the masses of other light nuclei. I venture to suggest[1] that the three-dimensional character of space may be finding expression in these formulas and regularities.

[1] E. E. Witmer, Phys. Rev. **42**, 316 (1932).

39. Generalization of Weinstein's Theorem. GABRIEL HORVAY, *Columbia University.*—Let[1] $(E_1-H_1)/(H_1-E_0) \geq p \geq 0$. Then $E_0 \geq H_1-(D_2/p)^{\frac{1}{2}}$. Weinstein's formula corresponds to $p=1$. The eigenvalue problem formulated as a Stieltjes momentum problem leads to an infinite system of inequalities. One particular class of this system consists of relations which are equivalent to results obtained by the Ritz variational method. The generalized Weinstein expression is the first member of a second class. A more complete discussion will be given elsewhere by K. Friedrichs and the writer.

[1] For notation see Phys. Rev. **55**, 70 (1939).

40. The Vapor Pressures, Heats of Vaporization and Melting Points of N^{14} and N^{15} Ammonia. HARRY G. THODE, *Columbia University.*—The vapor pressure differ-

ence between 70.6 percent $N^{15}H_3$ and ordinary ammonia has been measured for the liquids and solids over a range of temperatures by means of a differential oil manometer. The vapor pressure data for the liquids can be represented by the equation: $\log (P_1/P_2) = 0.943/T - 0.00317$, where P_1 is the vapor pressure of ordinary ammonia and P_2 that of the 70.6 percent material. The vapor pressure of ordinary ammonia is 0.371 percent and 0.174 percent higher than the heavy ammonia sample at 195° absolute (triple point of ammonia) and 239.6° absolute, respectively. The formula indicates that at 307.1° absolute the two samples would have the same vapor pressure. The heavier sample of ammonia has a heat of vaporization 4.31 calories per mol higher than that of ordinary ammonia. The triple points of the two samples differ by 0.077°, that of the 70.6 percent material being higher. Making simple assumptions the difference in the heat of vaporization and difference in triple points are found to be 6.14 calories and 0.109° calories, respectively.

41. Theory of the Double Fizeau Toothed Wheel. HERBERT E. IVES, *Bell Telephone Laboratories*.—R. W. Wood* has discussed a modification of Fizeau's method for determining the velocity of light, in which two toothed wheels are mounted at the ends of a long axle, the light traveling in one direction only. He concludes that, if the measured velocity of light remains constant when the apparatus is moving in the direction of the light ray, the axle not only alters in length, from the Fitzgerald contraction, but must twist. The present note points out that this "twist" is not a phenomenon which must be invoked solely to meet the requirements of special relativity, nor is it an effect peculiar to rotational motion superposed on the Fitzgerald contraction: It is actually a warping produced by the Fitzgerald contraction when any uniformly moving body is constrained to an orientation inclined to the direction of motion. Several special cases of moving rotating disks are studied, including the configuration of a single flat rotating disk, giving as answer to the Ehrenfest paradox, that the disk becomes "dished."

* R. W. Wood, *Physical Optics*, second edition, p. 690.

42. Preliminary Investigation of Cathode Rays. J. G. TRUMP, R. J. VAN DE GRAAFF AND R. W. CLOUD, *Massachusetts Institute of Technology*.—The absorption of cathode rays in the range up to 1500 kilovolts has been studied. A parallel beam of rays homogeneous in energy was obtained from a pressure insulated electrostatic generator and vacuum tube recently developed[1] for physical research and cancer therapy. Observations have been made of the penetration of the rays and of the ionization as a function of penetration in lead, copper, aluminum and water. Curves are given showing that with an initially homogeneous cathode ray beam the ionization as measured by a thin chamber reaches a maximum at a depth well below the surface of the absorbing material. The effect of scattering on the distribution of the ionization is discussed, particularly with reference to the possible application of cathode rays to therapy.

[1] J. G. Trump and R. J. Van de Graaff, Phys. Rev. **55**, 676 (1939).

43. Some Interesting Biochemical and Physical Effects at High Pressure. R. B. DOW, *The Pennsylvania State College*.—Many physical and chemical methods have been applied to the study of proteins in aqueous solutions but, in this respect, practically no use has been made of extremely high hydrostatic pressures. Collaborative studies in the writer's laboratory have shown that high pressure is an effective means of studying some aspects of protein behavior, as well as other biological systems. In particular, denaturation at high pressure has been studied for the following proteins in aqueous solution: hemoglobin, pepsin, rennin, and insulin. The energy relations for pressure denaturation are discussed and compared with heat denaturation. The possible relation of these experiments to current theories of protein structure are indicated briefly. Certain other effects have been observed in bovine blood[1] and in milk. Pressure disintegrates the erythrocytes in blood and coagulates it into a solid; it sterilizes milk by killing the lacto bacillus. In studying the latter it was observed that the effective pressure range extended from 3000 to 7000 atmospheres at room temperature, the degree of mortality depending on the magnitude of the pressure. The decrease of bacteria count was correlated with the change of hydrogen ion concentration that took place after the treated milk sample was allowed to stand for several hours. Time of exposure, intensity of pressure, and temperature are characteristics of pressure treatment that have been investigated in these studies.

[1] R. B. Dow and J. E. Matthews, Jr., Phil. Mag. **27**, 637 (1939).

SATURDAY MORNING AT 9:30 O'CLOCK

Palmer Laboratory, Room 309

44. Arcing Phenomena in Mercury Switches. C. G. SUITS, *General Electric Company*.—The influence of the gas and its pressure on the character of the arcing in mercury switches is investigated. In general, arcing occurs upon closing or opening inductive or non-inductive circuits on direct or alternating current. In the range of successful operation the duration of arcing is less than 0.02 second, being much longer upon closing the circuit than at interruption. In the current range employed excessive arcing at the closing position is not inherent, but is characteristic of the geometry of the switch chamber. For both the closing and opening positions, with direct current, the arc duration

becomes less through the series of gases argon, nitrogen, helium, and hydrogen, at the same pressure. For hydrogen, the arc duration is least at the highest pressure. The interrupting limit for alternating current increases through the series argon, nitrogen, helium, hydrogen, and high pressure hydrogen. The arc duration and the interrupting limit of this switch chamber with various gases and pressures correlate with steady state data for arcs in the same media. We conclude, therefore, that the heat transfer properties of the gaseous medium determine the electrical properties of the transient arc phenomena in this interrupting device. This is analogous to the previously reported correlation between the electrical characteristics of steady state arcs and the thermal properties of the medium.

45. Velocity of Mercury Ions in Mercury Vapor. K. H. KINGDON AND E. J. LAWTON, *General Electric Company.*—Measurements have been made with a cathode-ray oscillograph of the time of transit of mercury ions between two plates 5 cm apart in mercury vapor at various pressures and at a temperature of 120°C. For a range of values of E/p (volts per cm/mm) from 6000 to 20, the velocity of the ions is proportional to $(E/p)^{\frac{1}{2}}$. The velocity is 10^5 cm per sec. at $E/p=1000$. The measurements are being extended to smaller values of E/p in order to determine the pressure above which the high pressure diffusion theory of the mercury plasma should be applicable.

46. A Quartz Membrane Manometer of Small Volume and its Use in the Study of Pressure and Temperature in High Intensity Mercury Lamps. CARL KENTY, *General Electric Vapor Lamp Company.*—A flat quartz diaphragm (0.06 to 0.6 mm) is sealed at the edges to and in contact with a flat quartz disk with hole and capillary tube attached. The diaphragm has its motion amplified by a "rocker" having 3 legs nearly in line, the middle one resting on the diaphragm. A long pointer read with a microscope indicates an excess of pressure on the inside. Magnifications up to 10,000 are obtained. At 1 atmosphere the accuracy is $\frac{1}{2}$ mm. Gauges sealing directly to lamps have been developed for ranges from 1 mm to 25 atmospheres, operating at temperatures up to 800°C and having volumes as low as 5 mm³. At constant wall temperature and on d.c., P increased in the H1 lamp from 52 cm at 40 w (2.17 w/cm) to 107 cm at 745 w (42.3 w/cm) ($P=90$ cm at 400 w). The core diameter increased 4-fold. Temperature distribution curves similar to those of Elenbaas[1] fitted to these pressures have wall slopes indicating that conduction heat losses (A) increase 5-fold. Incorporation of this variation in A extends the range of Elenbaas' gradient formula.[2] Use of the axial temperatures, arc currents, gradients and cross sections, and the Saha and Langevin formulas indicates considerable departure from thermal equilibrium at 5 w/cm which increases rapidly below this point.

[1] W. Elenbaas, Physica **1**, 211, 673 (1934).
[2] W. Elenbaas, Physica **2**, 757 (1935); **7**, 568 (1938).

47. Temperature Dependence of the Work Function of Tungsten. JAMES G. POTTER, *Armour Institute of Technology.*—The Kelvin method is employed to obtain rapid measurements, in vacuum, of the contact potential between a tungsten filament at room temperature and a second filament heated to various temperatures. The capacity is varied between the two filaments, which are suspended parallel, by vibrating one of the filaments, under tension, by means of an alternating current passed through it in the presence of an applied magnetic field. The other filament is connected to an audio-frequency amplifier, which may be silenced by impressing on the electrical mid-point of the vibrated filament a potential equal to the contact potential difference between the two filaments. The immediate changes in contact potential, when the vibrated filament is heated over the temperature range from 300 to 1000°K, indicate a linear increase with temperature in the work function of tungsten of 6.2×10^{-5} volt per degree centigrade. In a vacuum with a measured pressure always less than 1.5×10^{-8} mm of Hg, after many hours of outgassing of the tungsten at temperatures up to 2900°K, variations in contamination, which occur comparatively slowly following moderate changes in temperature, are observed to produce changes in work function which could be interpreted erroneously to indicate temperature coefficients of magnitudes several times that stated above, and of either sign, depending upon the exact stage of the contamination.

48. A New Method for Photoelasticity in Three Dimensions. R. WELLER, *Ohio State University.*—It is possible to use the polarization caused by the scattering of light within a cloudy model in place of the usual analyzer in photoelastic investigations. This enables one to make analyses of three-dimensional stress systems very conveniently. One makes a model from a suitable transparent plastic which contains enough scattering particles to analyze satisfactorily a beam of polarized light. The model is then loaded and placed in a beam of plane-polarized light which has been collimated and passed through a slit. This beam illuminates a plane section through the model. Interference fringes appear in this section when it is viewed normal to the direction of the beam and also to the plane of polarization of the beam. One may place the model in any desired position with respect to the beam and thus observe all possible sections. One may also immerse the model in a liquid of the same index, if desired, to eliminate unwanted refraction.

49. A New Method for Measuring Young's Modulus. ALLEN KING, *Rensselaer Polytechnic Institute.*—The specimen in the form of a circular wire loop is fastened at one point to a rigid support. At the diametrically opposite point a magnetic field is applied. The frequency of an a.c. in the loop is adjusted until flexural vibrations occur in the plane of the loop. Then the resonance frequency f, the radius of the loop r, the linear density m, and the radius of the wire a are related to Young's modulus by the equation, $E=18.399mf^2(r/a)^4$. The method has been developed here as part of a program of metals research, particularly for the study of alloys. Preliminary data obtained by this method will be presented.

50. A Wide Range High Voltage Electrostatic Voltmeter. FRANCIS H. NADIG AND J. LLOYD BOHN, *Temple University.*—This instrument is the result of an effort to obtain high voltage measurements accurately and conveniently. The experimental instrument gives readings ranging from five kilovolts to fifty kilovolts. However, with slight modifications the instrument can be made to measure any desired range between several hundred volts to several hundred kilovolts. The scale has an equivalent length of six feet and readings can be made with an error of less than one per cent. The instrument reads both d.c. and effective a.c. voltages, and may be used on either a grounded or a floating system. The instrument is complete in itself and requires no auxiliary apparatus such as batteries, lamps or telescopes. It weighs approximately three pounds; is rugged, portable and ready for immediate use. The instrument should be of especial value in x-ray therapy where effective voltages could be used instead of effective wave-lengths.

51. Cathode Sputtering. CHAUNCEY STARR, *Massachusetts Institute of Technology.*—An empirical relationship has been found between the rate of sputtering of various metals and the total heat required to evaporate the metal. This total heat includes the heat capacity from room temperature to the melting point, the heat of fusion, the heat capacity from the melting point to the boiling point, and the heat of evaporation. For fixed glow discharge conditions, the sputtering data, with few exceptions, follow the law $m=c/q^2$ where m is the mass of sputtered material per ampere hour, c is a constant dependent on the discharge conditions, and q is the total heat for evaporation. This relationship is not in accord with that to be expected from either one of the present theories. The theory of local high temperatures with subsequent thermal evaporation predicts an exponential relationship. The theory of direct momentum transfer of the impinging ions with the metal atoms would predict a linear relationship. A new theory is suggested that involves a double evaporation process. Ion bombardment causes emission of the metal atoms by direct energy transfer, at a rate inversely proportional to the total heat for evaporation. This metal vapor condenses into a fine aggregate (metal powder) after leaving the cathode surface. Subsequent exposure to the heat of recombination of the ions and electrons near the cathode surface would again cause evaporation, the metal vapor thus produced depositing on nearby surfaces. Such a process would follow the inverse square law found empirically. There is also ample evidence for the existence of the intermediate metal powder state.

52. Convection and Conduction of Heat in Gases.* I. BRODY AND F. DE KÖRÖSY, *Ujpest.* (*Introduced by E. Wigner.*)—The diameter of the "stationary Langmuir film," b, around warm filaments in gases was at first determined by Langmuir's own method in A, Kr and N_2: it was calculated from the wattage dissipated by the gases and from the heat conductivity of the latter. The calculated film thickness beside a plane surface is 3.3 mm, 1.4 mm and 4.3 mm, respectively. The said diameter was then redefined as the distance of thermal interaction between two similar, warm filaments; temperature measurements revealed that this conventional definition corresponds to the 90°C isothermals, whereas Langmuir assigned this conventional limit to the 130° isothermals. b is a linear function of the temperature: $b_t=b_{1000}[1+(t-1000)\cdot 0.000255]$ and b_{1000} decreases with increasing molecular weight of the gases. b decreases with increasing gas pressure: $b/b_1=(p_1/p)^{0.42}$ and it increases somewhat slower with the diameter of the filament, a, than would correspond to the equation of Langmuir: $2B=b\cdot\ln\, b/a$. The detailed temperature field around warm filaments was determined under varied conditions. Evidence was gathered that, although 90 percent of the wattage lost can be accounted for by assuming pure conduction, the gas is definitely moving upwards within the film as well as outside of it.

* The paper is accepted under this title by the *Journal of Applied Physics* where it is scheduled to appear in the July issue.

53. The Dispersion of Supersonic Waves in Cylindrical Rods of Polycrystalline Silver, Nickel and Magnesium. SIDNEY K. SHEAR AND ALFRED B. FOCKE, *Brown University.*—The velocities of elastic waves in polycrystalline rods of silver, nickel, and magnesium were measured at supersonic frequencies ranging from 120 to 750 kilocycles. This was done by mounting the rods in a horizontal position so that one end was supported by a loop of silk thread and the other end passed through a diaphragm into a special box which was filled with transformer oil and which contained the quartz crystal source of supersound. Lycopodium powder scattered along the rod formed wave patterns when the rod was vibrating resonantly and hence wave-lengths could be measured directly. The products of these wavelengths and the corresponding frequencies as read on the wavemeter yield the required velocities. The dispersion theory of Giebe and Blechschmidt was tested by calculating theoretical curves for four of the six rods and comparing these with the corresponding experimental curves. Very good agreement with the theory was found in each case out to a frequency just below the so-called "dead zone"—a frequency region in which supposedly no longitudinal vibrations can exist. Here the theoretical and experimental curves separate; experimental points were always found in the "dead zone." No evidence was found of the anomalous dispersion predicted by the theory.

54. Absorption of Supersonic Waves in Water and in Aqueous Suspensions. G. K. HARTMANN AND ALFRED B. FOCKE, *Brown University.*—The absorption of supersonic waves in both water and in an aqueous suspension of lycopodium spores was measured at seven different frequencies ranging from 990 kilocycles to 2500 kilocycles in approximately equal steps. A piezo-electric quartz plate was used in each case as a sound source and was driven by an electron-coupled oscillator and two-stage amplifier capable of yielding 100 watts. The radiation pressure of the sound waves against a cone suspended in the field was measured directly with a chainomatic balance. The differences in the absorption coefficients found for lycopodium suspension and for water were compared with the classical theoretical

expectation as derived by Sewell. These differences approach more nearly the theoretical value as the frequency increases. This may be due to the relative nonrigidity of the spores at lower frequency—a situation which would violate the theoretical boundary conditions. The absorption coefficients were also determined at a frequency of 990 kilocycles interferometrically, using the theory of Hubbard. The balance and the interferometric methods agree as to the absorption in water within 9 percent, with reference to their mean.

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